



**U. S. NAVAL SUBMARINE
MEDICAL CENTER**

Submarine Base, Groton, Conn.

REPORT NO. 596

PERFORMANCE EFFECTS OF INCREASED AMBIENT PRESSURE

II. Helium-Oxygen Saturation and Excursion Dive to a Simulated Depth of 1100 Feet

by

James W. Parker, M. S.

Bureau of Medicine and Surgery, Navy Department

Research Work Unit MF12.524.004-9009.03

Released by:

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COMMANDING OFFICER
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10 September 1969





Depth gauge showing chamber pressure in feet of sea water during excursion dive to 1050 feet.

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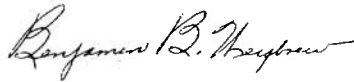
SUBMARINE MEDICAL RESEARCH LABORATORY

U. S. NAVAL SUBMARINE MEDICAL CENTER REPORT NO. 596

Bureau of Medicine and Surgery, Navy Department

Research Work Unit MF12.524.004-9009.03

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SUMMARY PAGE

THE PROBLEM

To determine whether any decrement in human performance can be measured by simple addition, letter cancellation, and choice reaction-time tests in a simulated helium-oxygen dive to a saturated depth of 800 feet with excursion depths of 1000, 1050, and 1100 feet.

FINDINGS

Few, if any significant decrements in the performance of the two divers were noted. In some instances, improvements were found not attributable to learning or practice. Subject motivation played a large part in score variation.

APPLICATIONS

This study provides additional information on the behavioral effects of exposure to high pressure helium-oxygen breathing gases under conditions of saturation and excursion diving. This information is relevant to man-in-the-sea and other exploratory diving research.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of an Independent Research Project MR011.01-5000—Physiological Limits in Saturation—Excursion Diving. The present report is No. 3 on this Work Unit. The manuscript was approved for publication on 10 September 1969, and designated as Submarine Medical Research Laboratory Report No. 596.

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ABSTRACT

Two experienced, commercial divers were administered a simple addition test, a letter cancellation test, a geometric forms test and a choice reaction-time test (RATER) at selected intervals before, during and after a simulated, helium-oxygen dive in a pressure chamber complex to a saturated depth of 800 feet equivalent with excursion dives to 1000, 1050 and 1100 feet. The compression rate was 3.5 feet per minute. Few, if any, significant decrements in performance on any of the measures were noted. In fact, in some instances, slight improvements were found which cannot be attributed to learning or practice effect. Most changes were postulated as being due to motivational factors. Future plans for validation of additional performance measures are presented.

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PERFORMANCE EFFECTS OF INCREASED AMBIENT PRESSURE:

II. Helium-Oxygen Saturation and Excursion Dive to a Simulated Depth of 1100 Feet

INTRODUCTION

The literature of submarine and diving medicine contains a number of studies designed to investigate the physiological effects of exposure to various gaseous mixtures at varying ambient pressures. By and large these studies have emphasized those physiological processes which, in one way or another, are involved with decompression sickness of obvious significance for diving medicine. In contrast, there have been relatively few studies aimed at ascertaining what, if any, psychophysiological and behavioral effects result from exposures to these stressful conditions. In 1937, a study by Shilling and Willgrube studied the effects of compressed air on the mental ability of 46 persons. Using arithmetic problems, number cancellation and a simple reaction-time test to light stimulus, they found a negative correlation between mental ability and the sensitivity to narcosis to depths down to 300 feet. They also noted that the rapidity of compression also affected the susceptibility with rapid compression resulting in dizziness. Using a manual dexterity test, Case and Haldane (1941) showed no significant deterioration in seven subjects at 250 feet. However, the results with an arithmetic test did show evidence of mental impairment with increase in both time and errors. They also report that at 300 feet the effects were more apparent. Using 14 subjects at four, seven, ten and 13 atmospheres Adolfson (1964) reported that hard work markedly increases the decrement in the performance of an arithmetic task. He also noted, as did Shilling and Willgrube, that the narcotic symptoms are more acute if the compression is rapid rather than slow. Bennett and his colleagues (1964) studied the narcotic effect of very rapid compression with air. In going from the surface to 400 feet in 20 seconds, data obtained from ten subjects performing on a two-choice reaction time task, showed no significant difference between expected values

and obtained values. However, in going to 500 feet in 20 seconds with the same comparisons showed a significant increase in reaction time (14-15%) together with symptoms described as euphoric. It should be pointed out that in these studies the subjects were experienced divers who were at the time of the experiment, occupied as escape training tank instructors.

A predecessor to the now well-known SEALAB series of saturation diving studies was Project Genesis, one of the early project series focused upon the problems of saturation diving. One study coming out of that series (Weybrew et al., 1964) investigated the psychological and psychophysiological effects of confinement in a Helium-Oxygen-Nitrogen atmosphere for 284 hours, at a simulated depth of 200 feet. Little, if any effects, were reported. However, a pilot study not in the literature was performed at the Submarine Medical Research Laboratory (SMRL) in which four subjects were subjected to pressures equivalent to 300 feet on compressed air. The results were very dramatic in that the effects of narcosis, or "rapture of the deep," were very apparent as indicated by performance decrements for tasks such as simple addition and two-hand coordination. One ancillary finding was based upon the premise that the divers' knowledge of the depth might have some "suggestive" effect on the onset of narcosis. Accordingly, another pilot study was undertaken, again with four subjects. In this study the depth was varied, randomly, up and down at several different increments and rates between 100 and 250 feet. The depth gauges inside the chamber were covered. The results appeared to bear out the general hypothesis that the narcotic effects may not become apparent at the depths previously reported.

Turning now to HeO₂ studies, Marshall (1951) showed that helium will cause narcosis at extreme pressures. According to Ben-

nett (1966), Keller, in a helium/oxygen mix, showed signs of narcosis at 1000 feet. At 200 feet, with a similar gas mixture (80% helium, 20% oxygen), Baddely (1965) did not find the average decrement, a screwplate and an arithmetical test, to be significantly different from control data at one atmosphere. However, using a 95%/5% helium-oxygen mixture at 600 and 800 feet with the ball-bearing test, the screwplate test and multi-choice reaction time, Bennett (1965b) showed definite impairment in four of six subjects during the first hour at 600 feet (compression time was 15 minutes). However, this initial decrement was followed by a period of slow recovery. Accompanying the impairment in two subjects were symptoms of dizziness, nausea and vomiting during the early stages at pressure. The other two subjects reported dizziness, but were reportedly able to prevent any performance decrement by self-control. During the first 20 minutes a much more severe decrement in performance was observed in four subjects. In summarizing these data, Bennett suggested the possibility that the observed performance decrements may not necessarily be the result of inert gas narcosis.

In the context of this background, this paper will present the results of performance studies made at a saturated depth of 800 feet, with a 5-minute excursion dive to 1100 feet, a 30-minute excursion dive to 1050 feet and a 2.75-hour excursion dive to 1000 feet. The study was carried out in the diving complex owned by International Underwater Contractors, Inc., at the Advanced Engineering Laboratories of Air Reduction Company, Inc. The gas mixture used was helium-oxygen. This is the second in a series of deep saturation dives conducted at this facility. The first dive used a saturation depth of 600 feet with excursions to 800 and 900 feet. The results of this earlier study were reported in the first paper in this series on the performance effects of increased ambient pressure (Weybrew and Parker, 1968).

METHOD AND PROCEDURE

Experimental Test Battery

Four tests were given at various times during the course of the dive. The test battery was composed of: (1) a simple arithmetic test consisting of several rows of eleven 1-digit numbers to be summed by the subject. The task was to add as many rows as possible in two minutes, entering each row-sum in the space provided. A sample of this test is included as Appendix I. (2) A cancellation test consisting of randomly intermixed O's and C's. The task for the subject was to cancel as many of the C's as possible in a 1-minute time period (Appendix II). (3) A geometric forms test similar to the Minnesota Paper Form Board was the third test. Three problems were given at each session and 10 seconds was allowed for each problem. A sample of this test is included as Appendix III. (4) The final test in the battery was the Response Analysis Tester (RATER). RATER presents a simple, choice reaction situation in which the subject is required to match a response key to each of four stimuli (geometric symbols). The sequence of stimuli, generated through solid state circuitry is an infinite, non-repeating, random series. The subject's performance, scored in terms of speed and accuracy, was recorded directly on counters. For the purpose of this study, the instrument was operated in the self-paced mode, thus providing scores for accuracy as well as for sequential reaction time of each subject.

The subject console of the RATER* was modified so that only a small metal box on which were mounted the four response buttons was inside the chamber. This box was connected to the subject console outside the chamber by a 5-lead, shielded cable through a pressure-proof connector installed in the chamber pressure hull. The switchbox for the subject was mounted on a metal plate such that it could be placed across the knees of the subject seated for the test.

*For a more complete description of RATER, the reader is referred to two Naval Submarine Medical Center (NSMC) reports: Parker, 1967, and Parker, 1968.



Figure 1—Subject seated in front of chamber port with RATER switchbox across knees.

Figure 1 shows a subject seated in the test position in front of a port. The RATER subject console containing the screen on which the stimuli appear was held up to the outside of the chamber port where it could readily be seen by the subject inside. Verbal communication was not required since the outside subject console has two lights which signal to the subject—an amber “ready” light which comes on three seconds before the test begins and a green “test” light which signifies the

beginning of the test simultaneously with the appearance of the first stimulus symbol. The test light and the stimulus screen go dark at the end of the one-minute test which is automatically timed to high accuracy by solid state circuitry in the control console. The test administrator then simply records the total response and correct response counts from digital counters mounted on the control console. Figure 2 illustrates the stimuli being presented through the chamber port.



Figure 2—RATER being administered through chamber port to subject inside.

Procedure

Several days before the beginning of the actual dive, the subjects were thoroughly trained on the RATER. First, the operation of the instrument was explained to them after which they were given a series of trials in order to facilitate the association of the four stimuli with their appropriate response keys. Sufficient trials were given outside the chamber to reduce the likelihood of learning effects being confounded with the effects of the "dive" once the experiment had begun. The pre-experimental or control data for RATER, as well as for the addition, cancellation and geometric forms tests were collected inside the chamber at standard sea level pressure just prior to the onset of the compression phase of the experiment.

Because of the limited time available once the dive began, it was necessary to coordinate the performance testing with other, rather extensive physiological measurement programs being carried out by the SMRL Physiology Branch personnel. A pre-dive conference was held for the purpose of a complete briefing and coordination of testing. The original schedule for the performance testing aspect of the experiment is presented as Figure 3. For the most part, this schedule was adhered to except for additional RATER testing as will be explained in the Results section of this report.

The general procedure for the test administration was as follows:

	Addition	Cancell.	Geom.	Rater	Diary
Pre-Dive	X	X	X	X	X
Half Way Down					
400 Ft.	X	X		X	
At 800 Ft.	X	X	X	X	X
At 800 Ft.					
After Rest	X	X	X	X	X
Pre-Excursion	X	X		X	X
At 1000 Ft.	X	X	X	X	X
At 800 Ft.					
Before Surfacing	X	X	X	X	X
400 Ft.				X	
Surface	X	X	X	X	X
Time					
Required:	2 min.	1 min.	0.5 min.	1 min.	1 min.

FIGURE 3.—PROTOCOL—PERSONNEL TESTS

The subject to be tested was alerted over the intercom to have his test materials ready and to signal when he was ready. The clock time of the test session was also given to the subject for the purpose of coordinating the data with the dive log. When the subject indicated that he was ready, he was given the "start" signal for the first test. At the end of exactly two minutes, he was told to "stop" and to prepare for the Cancellation Test. This test was timed to exactly one minute. The final, paper-pencil test was the Geometric Forms Test. The three problems in the set were individually timed at exactly ten seconds each. After the three paper-pencil tests, the subject was asked to go to the entry lock of the chamber for the RATER Test. If time permitted, two one-minute runs were made with RATER. Although the tests were given in the same order each session, the order of testing of the two subjects was reversed each session.

For reasons previously described, many of the tests were given concurrently with physiological tests. For example, while one subject was occupied with the ten-minute Ventilation Test, the other subject would complete the Performance tests; thus conserving many valuable minutes, particularly at the deeper depths.

Three excursion dives were made during the experiment. The first was to 1100 feet for five minutes, too brief an excursion time for any data to be collected. The next excursion was made to a depth of 1050 feet for 30 minutes. Whereas the schedule did not allow time to administer the paper-pencil test, RATER data were obtained upon reaching depth, and again just prior to returning to the saturation depth of 800 feet. The next day, the entire chamber complex was pressurized to a depth of 1000 feet where both subjects remained for nearly three hours.

At this depth, the entire battery of performance tests was administered. The remaining data were collected during decompression and subsequent to "surfacing."

Subjects

This section will present a brief profile of each of the two divers who served as subjects for this study. At the time of the study, Subject D. was 29 years of age, 5' 11" in height and weighed 155 pounds. He was single and had grown up in Huntington, Long Island, New York. He was the older of two boys in the family, his brother being 5 years younger. A high school graduate, he spent four years in the Air Force where he obtained a specialty rating as a pipefitter. He graduated from Coastal Diving School in Oakland, California as a hard-hat diver. At the time of the study, he had 5 years' experience as a SCUBA diver. He had no definite history of decompression sickness, although he recalled experiencing some undiagnosed wrist pain during a "job" completed 2 years earlier. He had wanted to be a Navy Underwater Demolition Team (UDT) diver, but because of a red-green color blindness (Ishihara), he did not apply, but went directly into the United States Air Force. Insofar as attitudes toward his being a subject in a study of this kind, D. stated he wanted to see if he could adjust to pressure and confined living conditions at extreme depths. He expressed the attitude that all the testing was to his benefit.

Subject F. was 25 years of age, 5' 10" in height and weighed 180 pounds. His early years were spent in Lyndonville, New York, where his father was engaged in farming. He is the youngest of 3 children, having an older brother and sister. He was married with one child and an expectant wife at the time of the study. A high school graduate, he spent 4 years in the Navy, attaining the rate of Third Class Equipment Operator, and was with UDT-21. He graduated from the Navy Underwater Swimmers School, Key West, Florida and had 6 years' experience as a SCUBA diver. He had no history of decompression sickness as such, although he reported having experienced "skin bends" on occasion. He had a very enthusiastic attitude

towards diving as a profession and indicated that it was the only way for him to earn a living. He felt proud to be a part of the experimental study, his prevailing attitude being that it was essential before going further in actual "at sea" operations. He expressed no objection to being a subject for all the various psychological and physiological tests which were a part of this study.

From the investigator's point of view, these two divers were excellent subjects. They repeatedly demonstrated their willingness to take the tests and allow the psychological and physiological data to be taken, often under rather trying conditions. In short, it is believed that the data to be presented in the next section of the paper represents the maximum performance of two highly cooperative subjects.

RESULTS

The results obtained during the dive will be presented and discussed separately for each of the measures, addition, cancellation, geometric forms, and RATER.

Addition Test

Figure 4 presents the results obtained from the single digit addition test for both subjects. Also shown on the abscissa is the

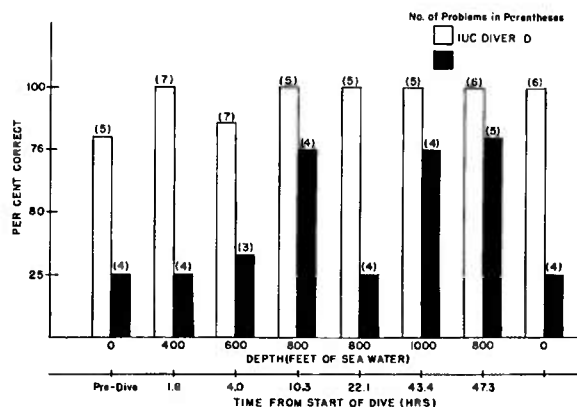


Figure 4—Results with Addition Test.

total elapsed time from the start of the dive. The numbers enclosed in parentheses at the top of the bars indicate the number of problems attempted during that particular ses-

sion. Obviously, for one subject, D. little change in performance is indicated. He consistently made perfect scores on the problems he attempted. Also, there is little difference in the number of problems attempted as the study progressed. The other subject, F. on the other hand, showed more variability in addition accuracy, and, attempted fewer problems than did his partner.

The changes in accuracy scores during the excursion dives to 800 feet were in opposite direction, the first one showing a drop in accuracy, and the second testing session at 800 feet (10.3 hours), showing an increase in accuracy as compared to the same score obtained at 600 feet. The only explanation offered for these conflicting results is that the second session at 800 feet took place after a regular night's rest and after breakfast, but before any daily activities had begun. The fact that F., at 1000 feet again showed improvement in arithmetical performance contraindicates any significant narcotic effects of the breathing mixture. Furthermore, upon his return to 800 feet, F. showed approximately the same level of performance. Finally, upon "surfacing," F. reverted back to his pre-dive and descent level of performance both in accuracy and in the number of problems attempted. This subject's spurt during the deep excursion may possibly be explained by enhanced motivation resulting from the success in the saturation and excursion dive to that point in the experiment. Similarly, the subsequent decline in performance at the "surface" may also have been the result of a decline in motivation coincident with release from the chamber. In short, beyond the fact that no evidence of narcosis is brought out by these results, little else can be inferred from the data.

Cancellation Test

The results obtained with the Cancellation Test are shown in Figure 5.

As in the previous graph, the abscissa has two scales showing the depth at which the data were obtained as well as the elapsed time since the start of the dive. The ordinate shows reaction time in seconds. This score is

computed simply by dividing the number of cancellations made in one minute by 60, thus providing a measure of serial reaction time. The number enclosed in parentheses over the bar is the number of errors* made during the 60-second test.

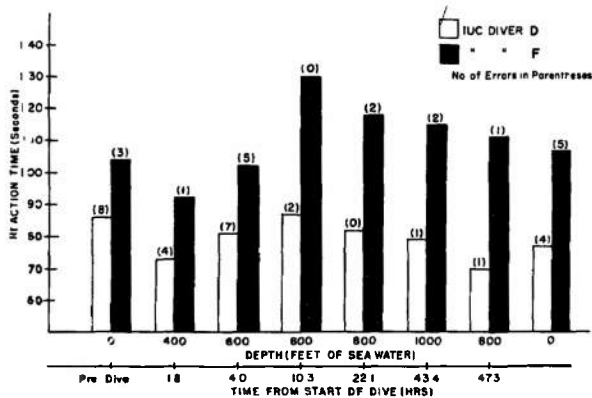


Figure 5—Results with Cancellation Test.

Obviously, the differences between the two subjects is remarkable. Throughout the series D. demonstrated a much shorter reaction time than did F. Their curves, however, tend to parallel each other in slope, although F. tended to slow down more upon reaching 600 feet and made much less recovery than did D. Possibly noteworthy is the fact that both the error scores and reaction time increased for both subjects upon reaching the depth of 600 feet for the first time (dive time 4 hours); however, cancellation accuracy did not appear to be affected for either man on subsequent depth excursions. D. was quite consistent, his reaction time varying between 0.7 and 0.92 seconds. Considering D's. curve from the standpoint of narcosis, there is no demonstrable effect, since his response time decreased with depth, instead of increased (i.e., slower reaction time) as might be expected if the gas mixture used had produced a narcotic effect at increased pressure. F's. performance on the other hand, is somewhat more difficult to interpret. The geometric forms test did not result in usable data. For

*This error score consisted of the sum of the errors of commission (cancelling an O rather than a C), and errors of omission (failure to cancel a C).

some unexplainable reason, both subjects made similar errors with almost equal frequency. Moreover, the small number of problems making up one testing session, negated any useful information.

RATER Scores

Results obtained with RATER are shown in Figures 6, 7 and 8. The graphs have been divided into three phases for clarity in presentation. These are: Descent, Ascent I and Ascent II. The two ascents were necessitated by the fact that after reaching a depth of 30 feet on the first ascent, some minor symptoms were reported by one of the subjects making it necessary to recompress to a depth of 525 feet followed by the standard decompression schedule back to the surface.

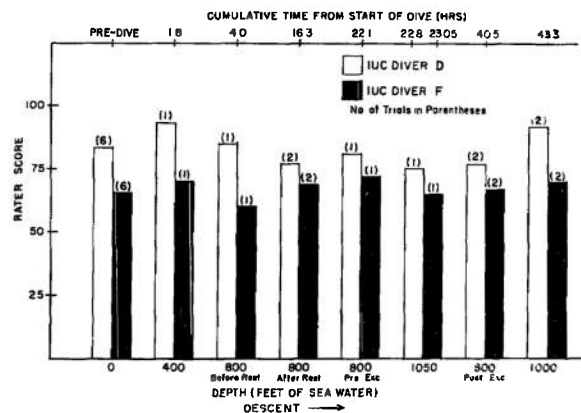


Figure 6—Results with RATER—Descent.

Figure 6, which shows the data for the descent indicates little change in RATER scores as the pressure increased. The scores achieved by the two subjects show only differences which might be expected by chance variation. In fact, both subjects showed slightly increased scores, indicating better performance scores at a depth of 1000 feet when compared with the pre-dive, control data taken at normal atmospheric pressure. This graph also shows the scores obtained from both subjects just before and just after excursion dives to increased depths. For D., the excursion dive was to 1100 feet, at that time a new

world record for helium-oxygen diving, and for F., to 1050 feet. D. remained at the 1100 foot depth for 5 minutes. It was not possible to obtain any data at this depth due to the limited time available and the necessary medical observation. The results for D. show no significant change either just before, or just after, his record-breaking excursion dive. On the other hand, F.'s RATER scores, both pre- and post-excursion to 1050 feet, were above his pre-dive level as well as higher than those obtained at 400 and 800 feet previously. Fortunately, during F.'s excursion dive to 1050, it was possible to obtain RATER data. He was tested immediately after reaching this depth, and again, prior to his leaving the 1050 foot depth and returning to 800 feet, the saturation depth. Although F.'s second score at 1050 feet was somewhat less than that upon first reaching this depth, it was not construed to be significant, since it is approximately equivalent to his pre-dive or control score. Similarly, F.'s post-excursion score again was not significantly different from his pre-dive or pre-excursion scores.

It might be well to interject a comment regarding the assumptions under which the RATER data were collected. As already mentioned, the time restrictions during "deep" excursions are severe and, as a result, it was possible to obtain only one, and sometimes two, trials at a given measurement session. This fact notwithstanding, the nature of RATER test is such that although it might be argued that more data would be desirable, the scores obtained during the numerous trials throughout the "dive" coupled with the lack of significant variation between sessions (depths) support the general assumption that results based on 1 or 2 trials at a time are meaningful and that the conclusions drawn from them also are, at the very least, suggestive.

The next day after the record-breaking excursion dives, the entire chamber complex was pressurized to a simulated depth of 1000 feet where it remained for two and three-quarter hours. Interspersed on a "time-available" basis with the medical and physiological tests, a RATER test sessions for both subjects were completed immediately upon

reaching, and just before leaving, the 1000-foot depth. Since their scores were not significantly different at either time, they have been combined for each subject (Figure 6). As can readily be seen, neither subject showed any decrement whatsoever. In fact, D., achieved one of his highest scores up to that point in the experiment.

In brief, during these excursion dives to extreme depths, both subjects were being continuously observed for any signs of impairment or narcosis. At no time was there any evidence of detrimental effects and the results with RATER and the other performance tests bear this out. It is beyond the scope of this report to comment upon the possibility of significant physiological changes during these deep dives. The results can be found in reports published by the Physiology Branch of the Submarine Medical Research Laboratory.

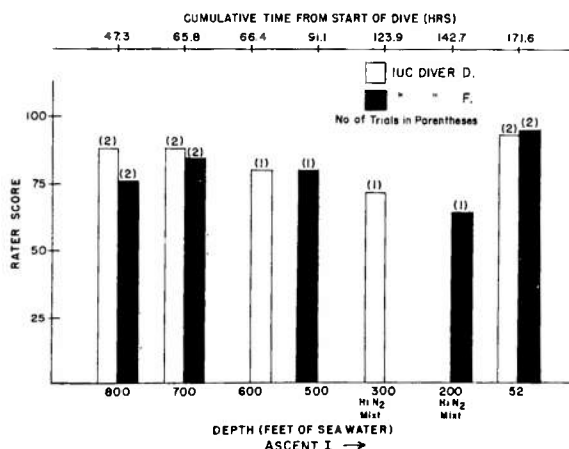


Figure 7—Results with RATER—Ascent I.

Turning now to the graph for Ascent I (Fig. 7), we again find no significant decrement upon return to 800 feet from the 1000 foot, 2³/₄ hour, excursion dive. (Compare last session Fig. 6 with first session Fig. 7.) After the outset of the decompression phase, data were again collected at 700 feet and, as before, no significant changes in the scores were noted. Similarly, data collected from F. at 600 feet, and from D. at 500 feet again failed to show any significant decrements in the RATER scores. At 300 feet, D. breathed

a high-nitrogen gas mixture, which was coincident with a slight decrease in the RATER score, a decrement not thought to be significant. The same mixture was breathed by F. at 200 feet with the same apparent results. The subjects were not tested again until they had reached 52 feet on the way to the surface. As might be expected, both divers were somewhat excited by the anticipation of the end of the experiment and, as a result, the RATER scores were higher (Fig. 7)—this, despite the fact that one of the subjects was experiencing some discomfort. Shortly after this, both subjects were repressurized to a depth of 525 feet where they remained overnight. Decompression was resumed the following morning.

Turning now to the graph for Ascent II (Figure 8), it is readily seen that the scores

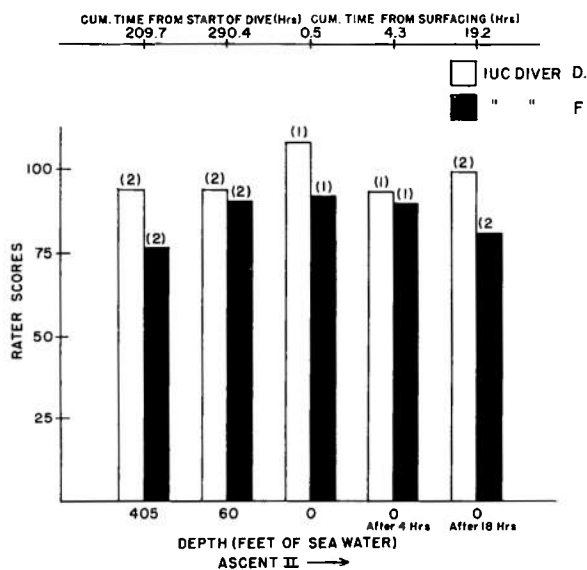


Figure 8—Results with RATER—Ascent II.

remained at a consistently high level, commensurate with the pre-dive, control data. At the 405 foot level, F. still was experiencing some discomfort and this is perhaps reflected in his somewhat lowered score at this depth when compared with those achieved at 52 feet. However, his 405 foot score still appears to fall within the average range for his RATER scores prior to this phase of the study. The final data taken under pressure were obtained at 60 feet with no remarkable change noted.

Immediately upon surfacing almost 13 days after entering the chamber, the post-dive control data were obtained with the subjects still in the chamber. The recovery data were collected four hours after surfacing and again eighteen hours after surfacing. The scores both subjects achieved were somewhat higher than pre-dive control data. The subjects reported no untoward effects from the thirteen days' exposure to pressure; except of course, the "relief" of being released from the chamber.

DISCUSSION

In discussing the results of the performance testing in this record-setting dive on a helium-oxygen breathing mixture, the most outstanding finding is that there was no convincing evidence of narcosis of the type experienced by divers at much shallower depths (200 feet) using compressed air as the breathing medium. There were variations in the scores, but the changes were always in the direction opposite to that which would be expected had there been any narcotic effects. No attempt will be made in this report to explain the improvement noted in the scores except to say that the effects of learning were thought to be minimal. The subjects were given many trials with the RATER prior to the start of the experimental run and prior to the collection of the pre-dive control data. The results of previous studies with RATER (Parker, 1968) have shown that the practice effects were negligible after five to eight practice trials, a practice criterion exceeded by both of the subjects in this study.

A second, possible explanation for the improvement in RATER scores, independent of "depth," is motivation. Since RATER was utilized in the self-paced mode of operation, it is possible to vary the score achieved simply by the amount of effort expended by the subject. By working slowly and deliberately, the number of errors committed can be held to a minimum and the overall score markedly reduced. It may be recalled that the decision to use RATER in the self-paced mode was based upon the desirability of obtaining a measure of sequential reaction-time, a type of behavior postulated to be a "sensitive"

indicator of incipient gas narcosis. Moreover, the RATER, self-paced score was more comparable to the scores on the paper-pencil cancellation test, since, like the cancellation task, the total number of responses and, indirectly, the response accuracy, is a reflection of both effort or motivation and discriminative ability. On the other hand, scores obtained via the auto paced mode (fixed stimulus—presentation rate) would not provide an objective measure of motivation.

One additional comment is appropriate. At the time of the collection of the data reported herein, there were no known data bearing upon the question of the most probable effects of gas narcosis upon RATER scores. However, it may be recalled that the results of a pilot study demonstrated significant decrements in addition performance in compressed air at the equivalent pressure of 300 feet (Weybrew and Parker, 1968).

To rectify this gap in the available data on the paper-pencil tests and RATER, a series of studies are being undertaken at SMRL to collect performance data from subjects in compressed air at depths to 300 feet. It is expected that the narcotic effect of the nitrogen content of atmospheric air at these depths will be quite dramatic and by comparison will increase the value of the results of the 1000 foot dive reported in this paper.

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APPENDIX I—Arithmetic Test

1	2	7	3	2	3	1	1	2	8	0
4	6	8	8	6	8	6	5	5	8	7
3	6	6	9	5	5	9	5	2	3	6
2	2	5	0	5	1	4	8	1	7	9
0	5	8	7	5	8	3	1	8	1	0
3	6	1	2	5	8	3	9	1	9	7
8	3	8	9	1	3	0	6	4	3	9
1	5	9	3	2	8	7	0	5	4	9
9	9	2	6	1	3	8	6	2	2	5
8	0	9	8	0	8	5	8	8	7	7
0	7	5	1	7	7	4	0	0	5	3
3	6	6	2	5	9	4	7	3	3	6
9	2	5	0	9	3	5	8	6	5	8
7	2	9	6	1	7	2	3	8	9	8
6	8	9	0	3	9	7	6	3	1	6
1	1	9	8	3	5	3	8	9	5	2
4	9	3	5	7	2	4	1	8	0	6
7	1	7	8	1	9	2	8	7	3	0
5	2	7	7	9	0	9	1	9	8	9
7	2	2	4	4	1	7	2	7	1	4
6	1	6	3	9	8	2	4	7	4	1
9	0	4	5	4	3	1	2	4	3	8

APPENDIX II—Cancellation Test

Series 15

Group

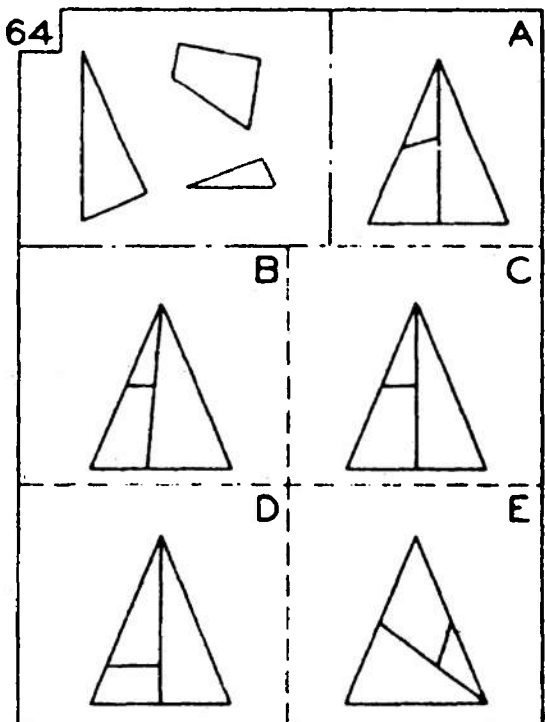
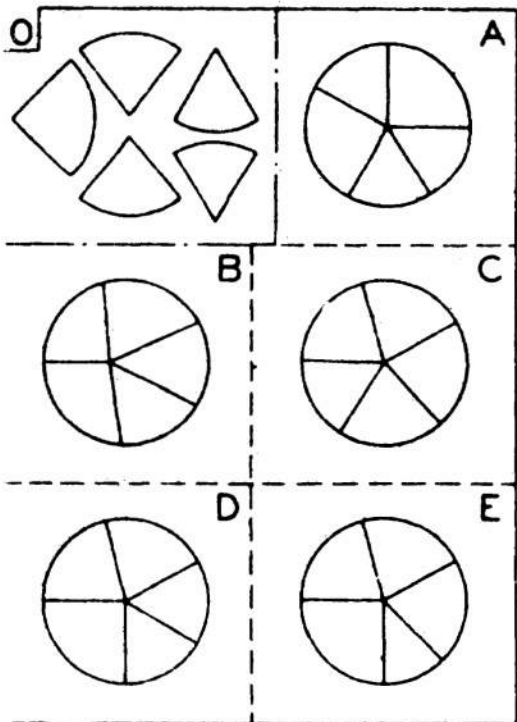
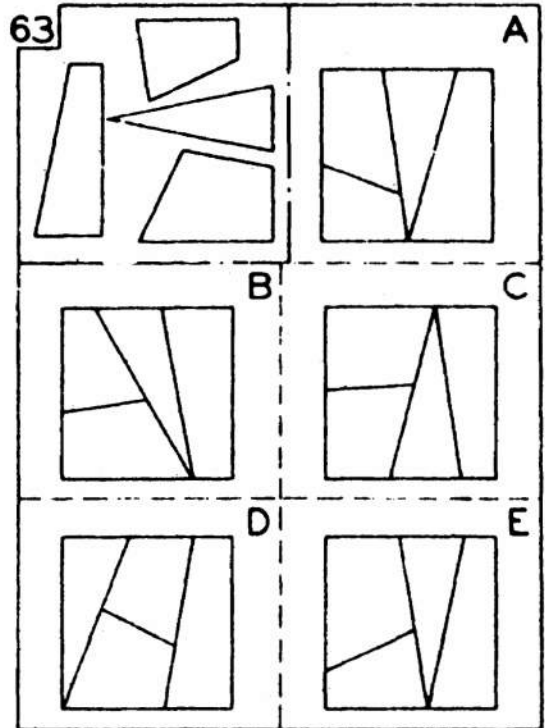
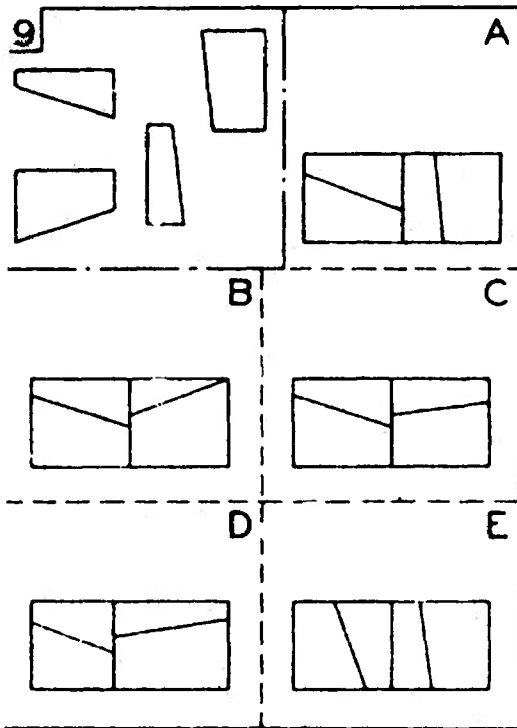
Time _____

Instructions: Below are listed a series of capital O's with capital C's interspersed. The task is to work from left to right making a mark through each C. Work as fast as you can for 1 minute. You are not necessarily expected to finish. However, should you finish, please record on the sheet exactly the time taken.

OOOOCOOOCCCCOOCOOOOOCCOOCOOOCCOOCOOOCCOOC
OOOOOOCOOOOOOOOOOOOOOCOOOOOCOOOOOOOOOOOOO
OOOOCOOOOOOOOOOCOOOOOOOOOCCOOOOOCOOOOOOOOO
OOCOOCCOOOOOOOOCOCOCOOOOOCCOOCOOOOOCOOOO
OOOOOOOOCOOOOOOOOOOOOOOOOOOOOOOOOOOOOOCOOOO
OOOOCOCOCOOOOOOOOOCCOOOOCOOOOCOCOOOOOCCOOC
OOOOOOOOOOOCCOOOOCOOOOOOOOOOOOOOOOOOOCCOOO
OOOOOOOOOCCOOOOOOOOOOOCCOOOOOOOOOOOOOOOOO
OOCOOOOOOOOOOOOCOOOOOOOOOCCOOOOCOOOOOOOOO
OOCOOOOOCCOOCOOOCOOOOOOOOOCCOOOOOCCOOCOOO
OOCOOOCOOOOOOOCCOOCOOOOOOOOOOOOOOOOOOOOO
OCCOOOOOOOOOCCOOOOOOOOOCCOOOOOCOOOOCOCOOOC
OOOOOOOOOOOCCOOOOOOOOOCCOOOOOCCOOOOOCCOCO
OCCOOCOOOOCOOOOOOOOOOOOOCCOOCOOOOOCCOOC

APPENDIX III—Geometric Forms Test

APPENDIX A Arithmetic Test



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13. ABSTRACT			
<p>Two experienced, commercial divers were administered a simple addition test, a letter cancellation test, a geometric forms test and a choice reaction time test (RATER) at selected intervals before, during and after a simulated, helium-oxygen dive in a pressure chamber complex to a saturated depth of 800 feet with excursion dives to 1000, 1050 and 1100 feet. The compression rate was 3.5 feet per minute. Few, if any decrements in performance on any of the measures were noted. In fact, in some instances, slight improvements were found which cannot be attributed to learning or practice effort. Most changes were postulated as being due to motivational factors. Future plans for continued validation of the performance measures used are present.</p>			

14.

KEY WORDS

LINK A

LINK B

LINK C

ROLE

WT

ROLE

WT

ROLE

WT

Decompression Sickness